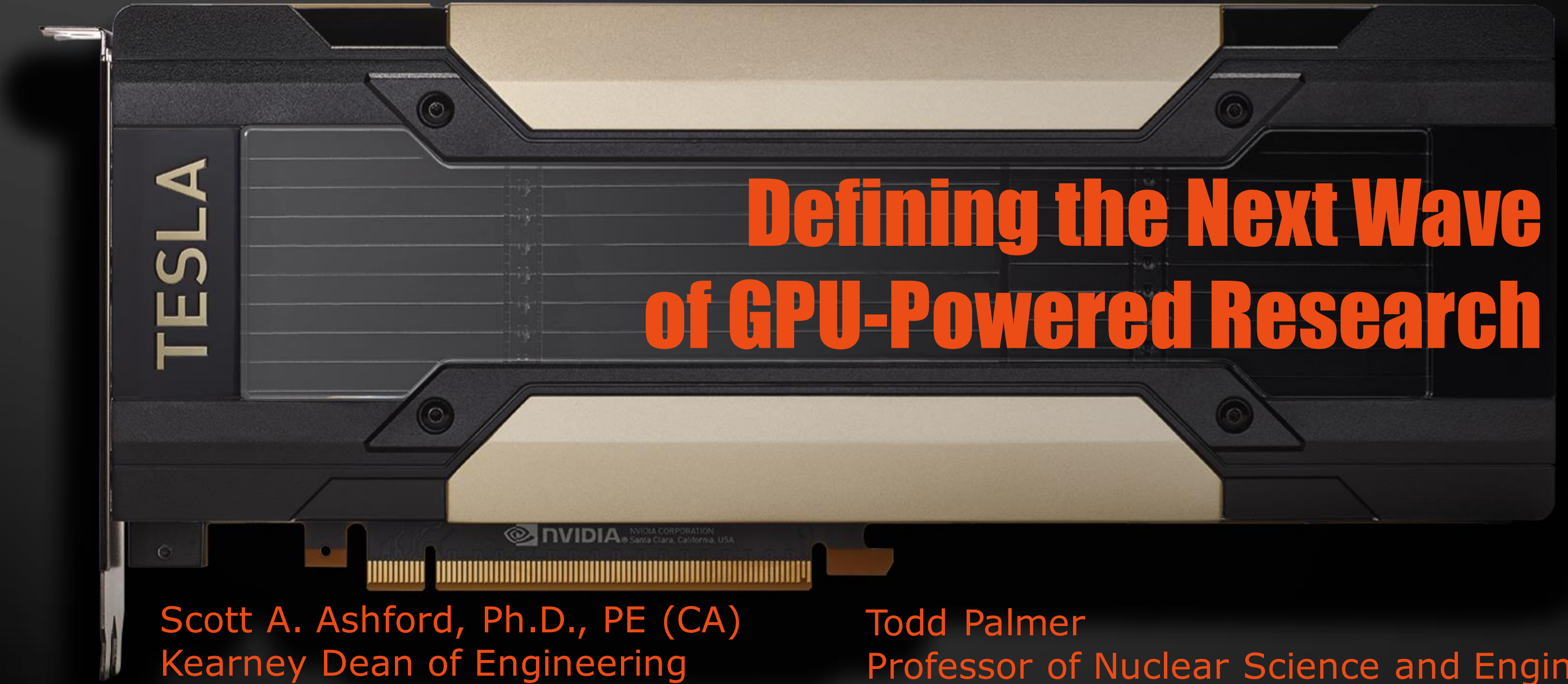
Oregon State University

COLLEGE OF ENGINEERING



Defining the Next Wave of GPU-Powered Research

Scott A. Ashford, Ph.D., PE (CA)
Kearney Dean of Engineering

Todd Palmer
Professor of Nuclear Science and Engineering

Mike Bailey
Professor of Computer Science

Alan Fern
Professor of Computer Science

Oregon State University
College of Engineering

#2

Computer Science degrees awarded

#4

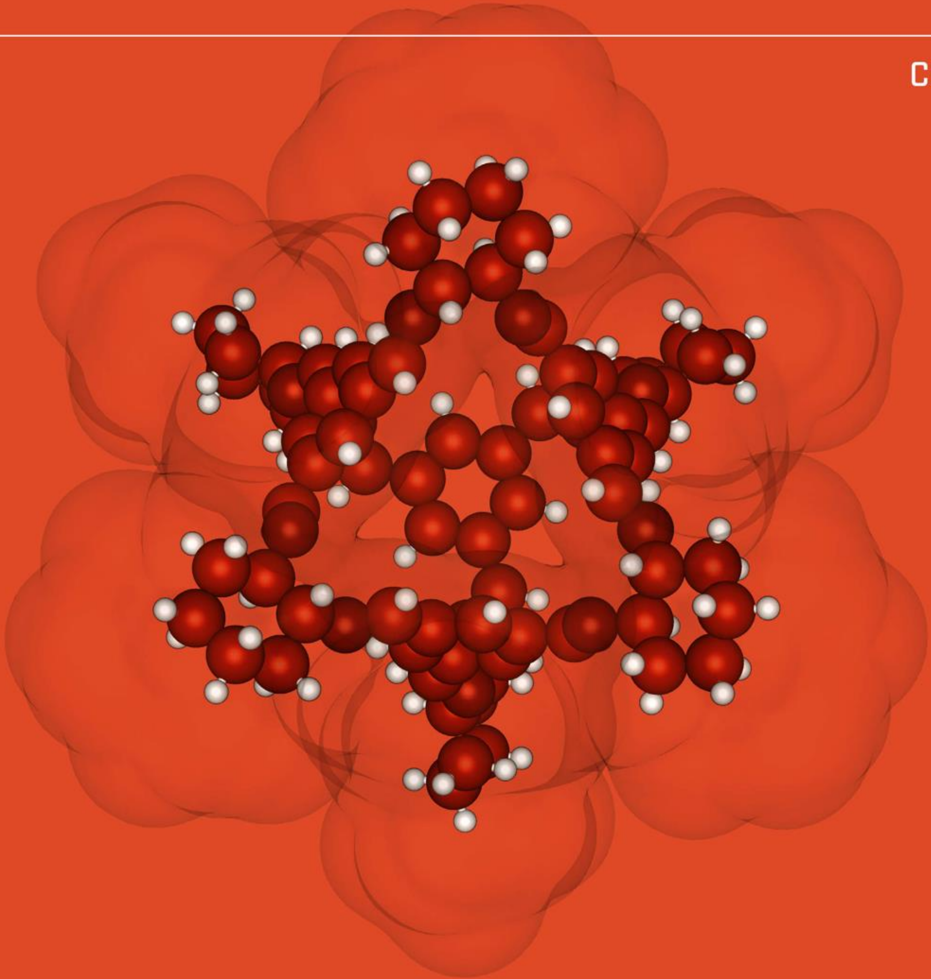
Robotics program

BEST
ONLINE PROGRAMS
U.S.News & WORLD REPORT
BACHELOR'S
2019

#5 Best Online
Bachelor’s Programs

#12 Best Online Graduate
Engineering Program

COLLEGE OF ENGINEERING



STRATEGIC PLAN
2020-2025

Oregon State University

Oregon State University
College of Engineering

Oregon State University
College of Engineering

“Today’s announcement reflects OSU’s commitment to its researchers and seriousness to lead in AI research.”

-Jensen Huang (Oregon State University, ’84 B.S. and ’09 Honorary Ph.D., Electrical Engineering)
Founder and CEO, NVIDIA

GPUs in Research

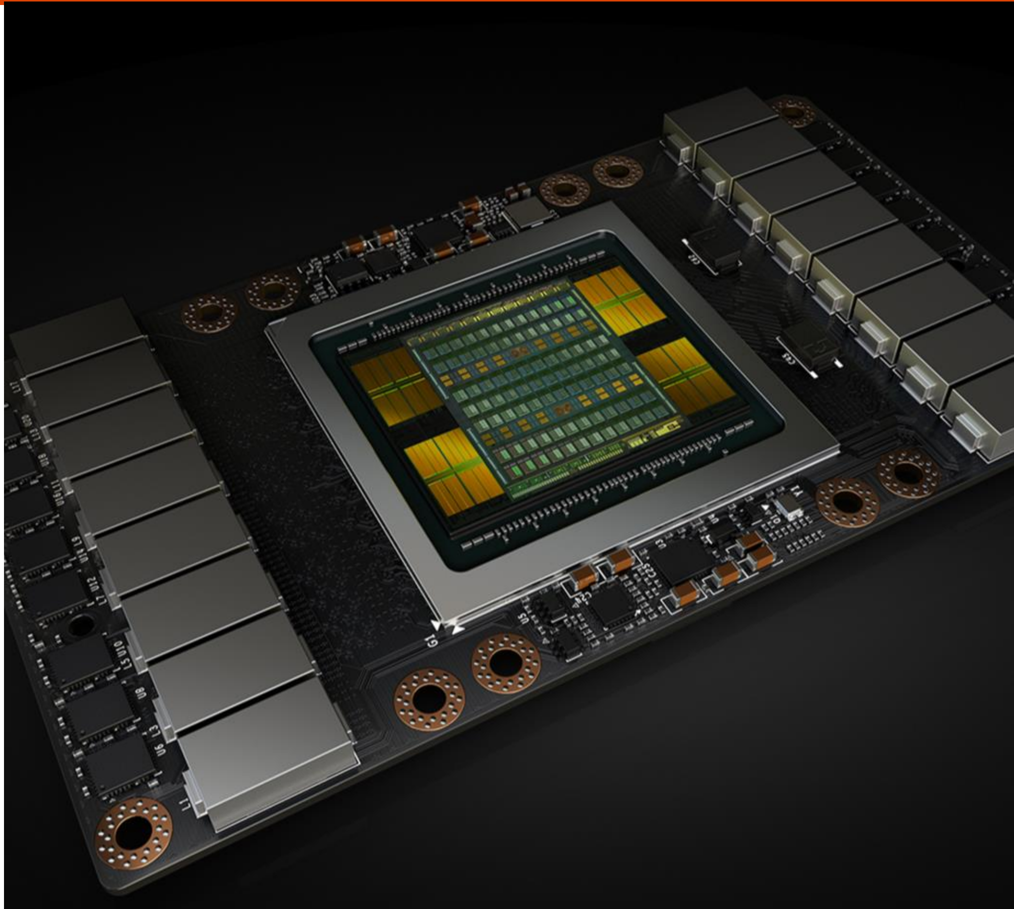
Mike Bailey, professor of computer science

- 30 years of experience in the computer graphics and high-performance computing worlds.

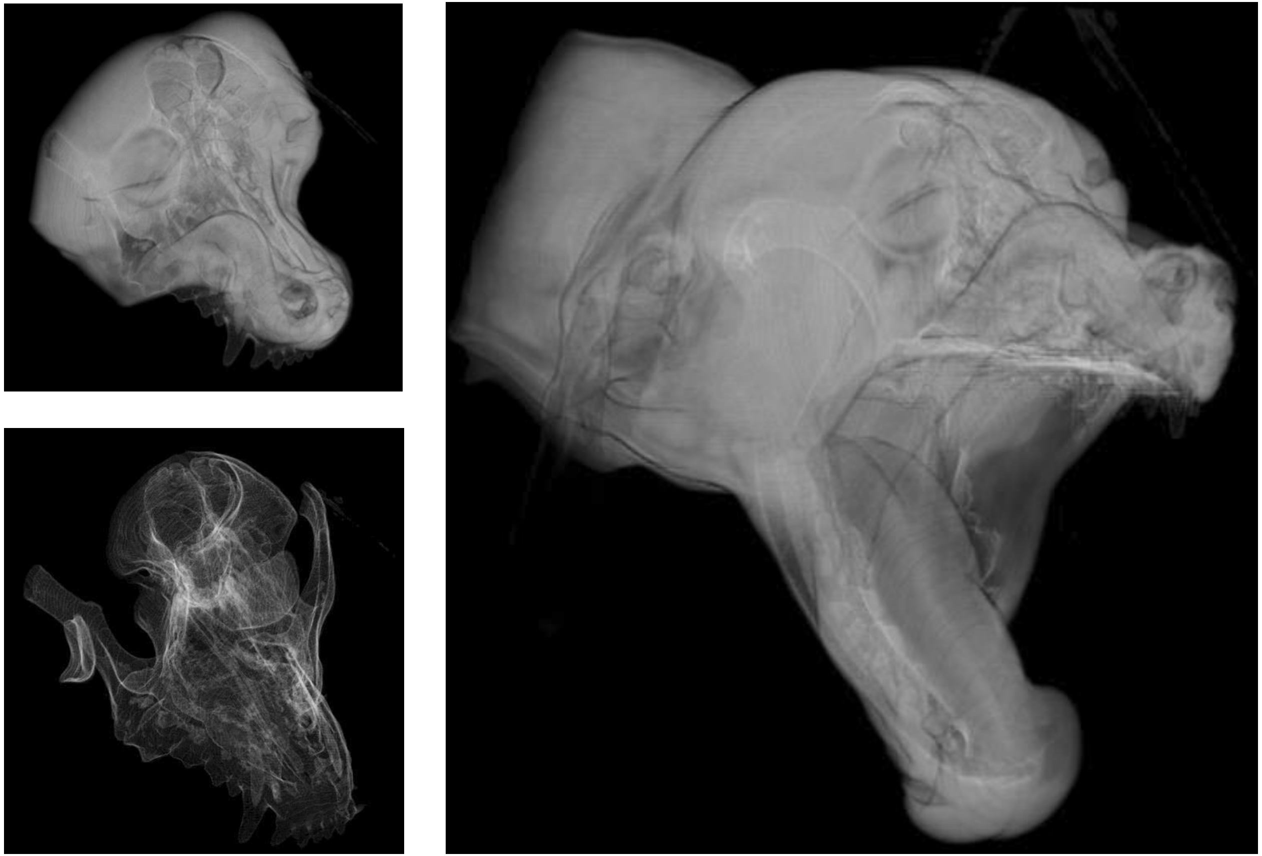
The World's Greatest Invention

Amazing advances enabled by GPUs:

- Animation
- Art
- Bioinformatics
- Data Visualization
- Machine learning
- Robotics
- Simulation
- Virtual and Augmented Reality

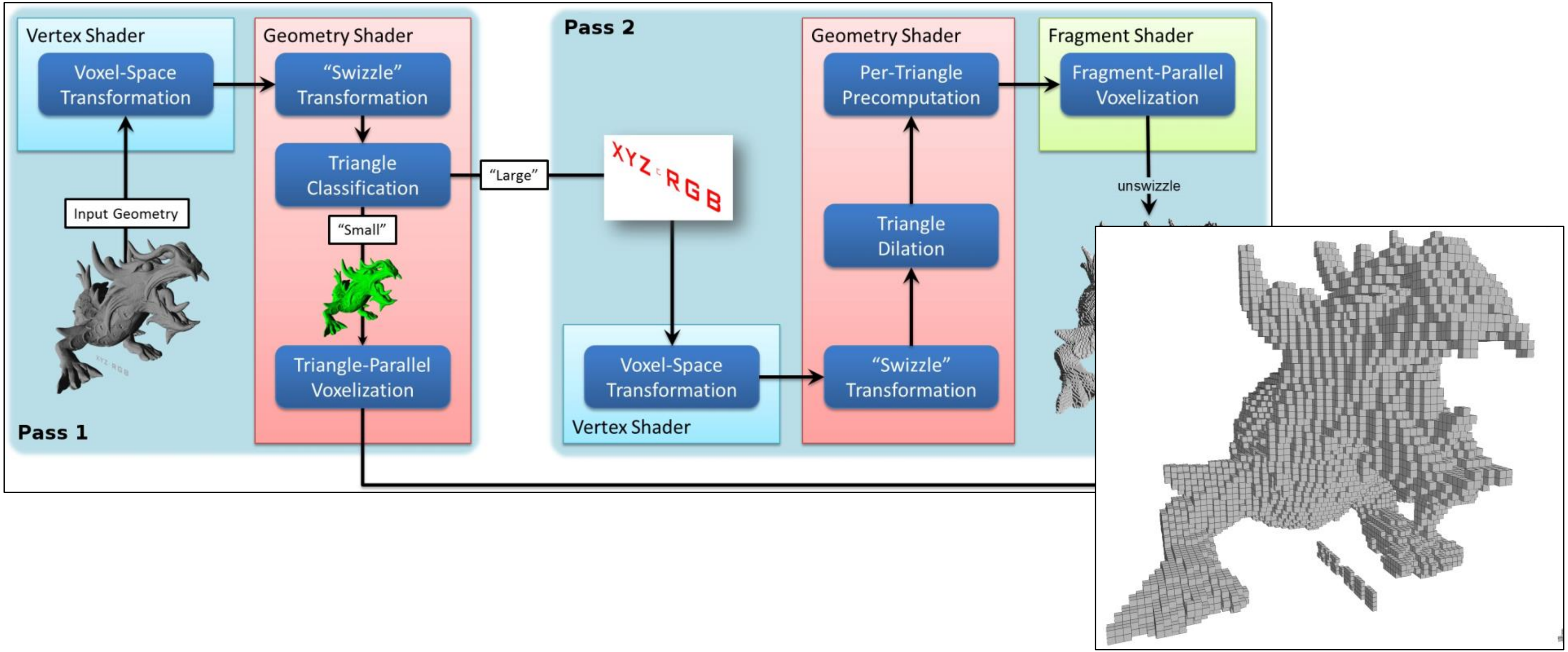


Veterinary Medicine



Chris Schultz

Real-time GPU-based Voxelization



Randy Rauwendaal

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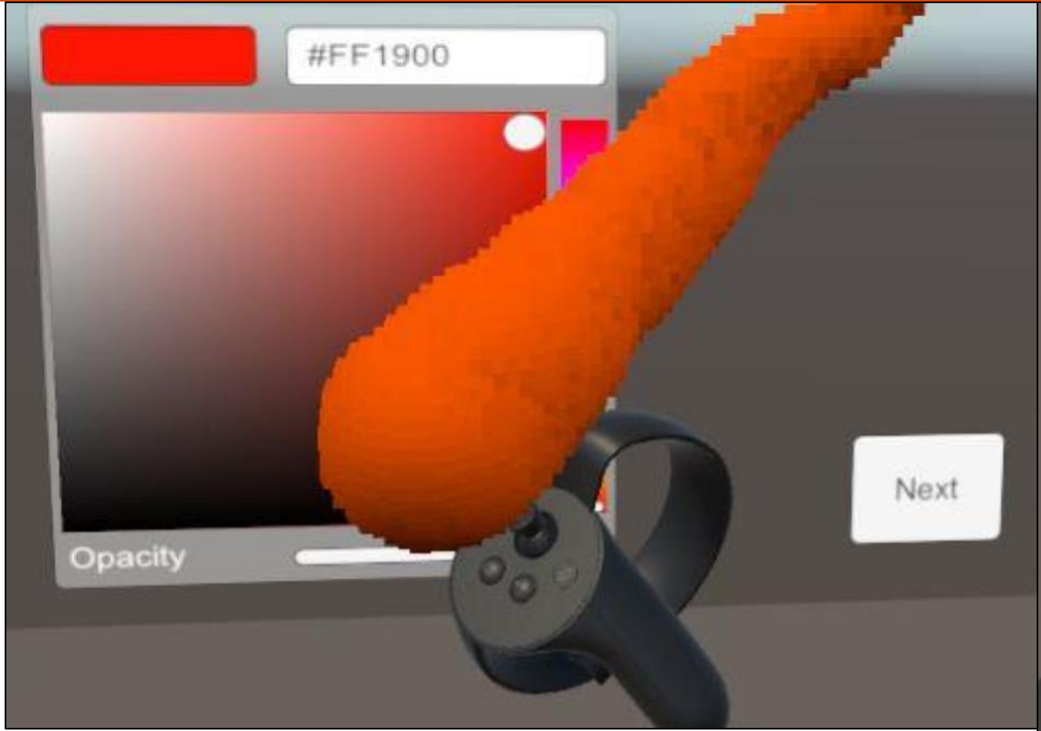
College of Engineering

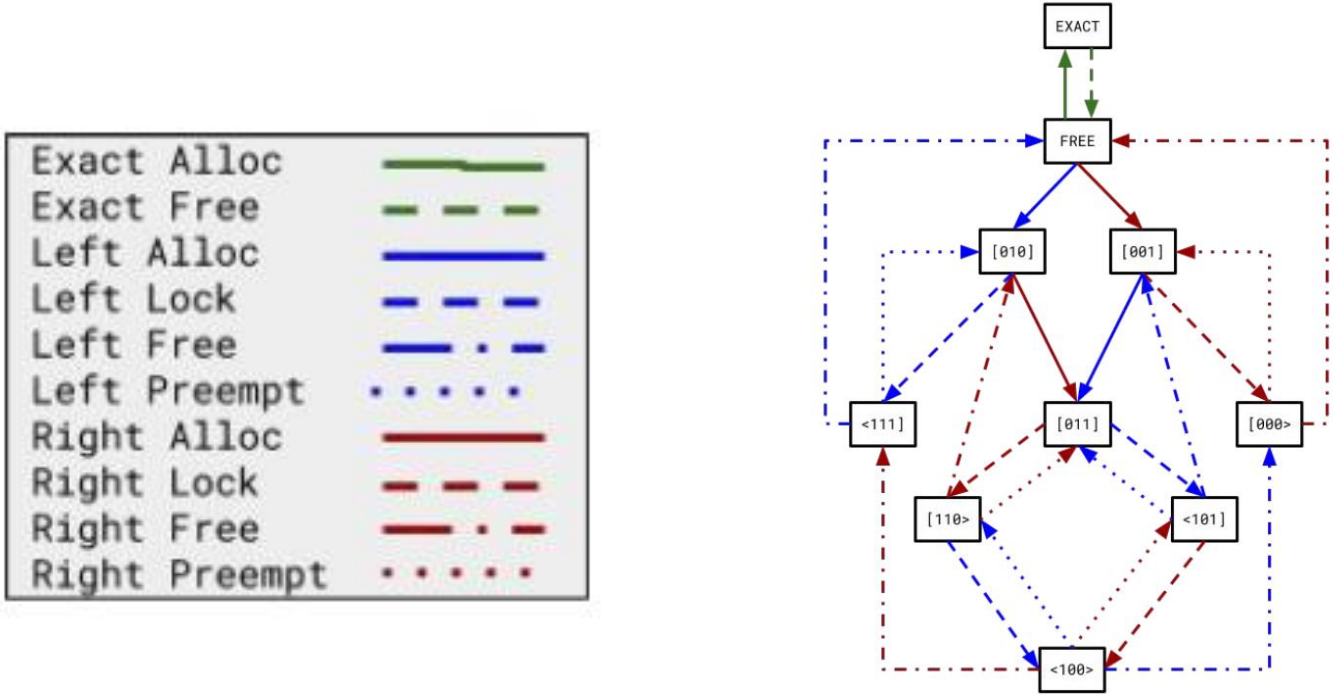
PolyVox



A Voxel-based Virtual Reality 3D Paint Program

Richard Cunard, Braxton Cuneo, Chris Bakkom

Faster Lock-free Buddy Memory Management for GPU Applications

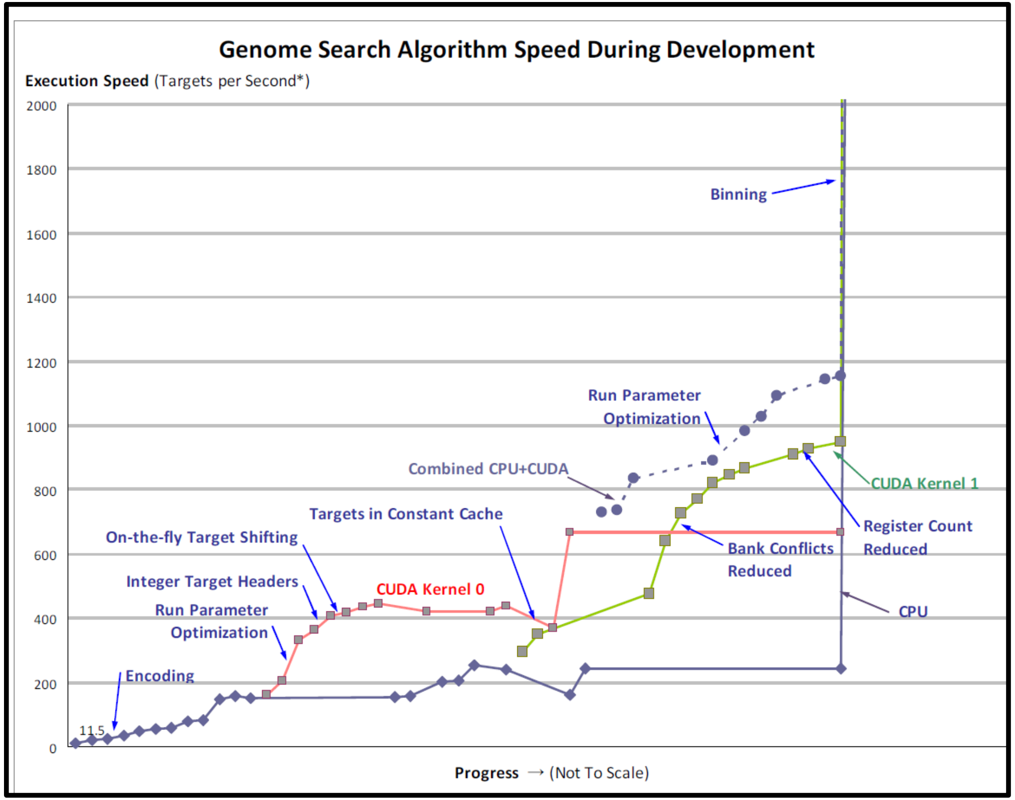


Braxton Cuneo

Oregon State University
College of Engineering

GPU Acceleration of Genome Matching

Performance increased from 11.5 targets/second to 2,000 targets/second



Ben Weiss

Money doesn’t grow on trees…

GPU-Related Subjects

Computer Graphics: OpenGL

(170 students in Fall Quarter 2019)

http://cs.oregonstate.edu/~mjb/cs550

Computer Graphics Shaders

(110 students in Winter Quarter 2020)

http://cs.oregonstate.edu/~mjb/cs553

Vulkan

(70 students in Winter Quarter 2020)

http://cs.oregonstate.edu/~mjb/cs519v

Scientific Visualization

(80 students in Spring Quarter 2019)

http://cs.oregonstate.edu/~mjb/cs553

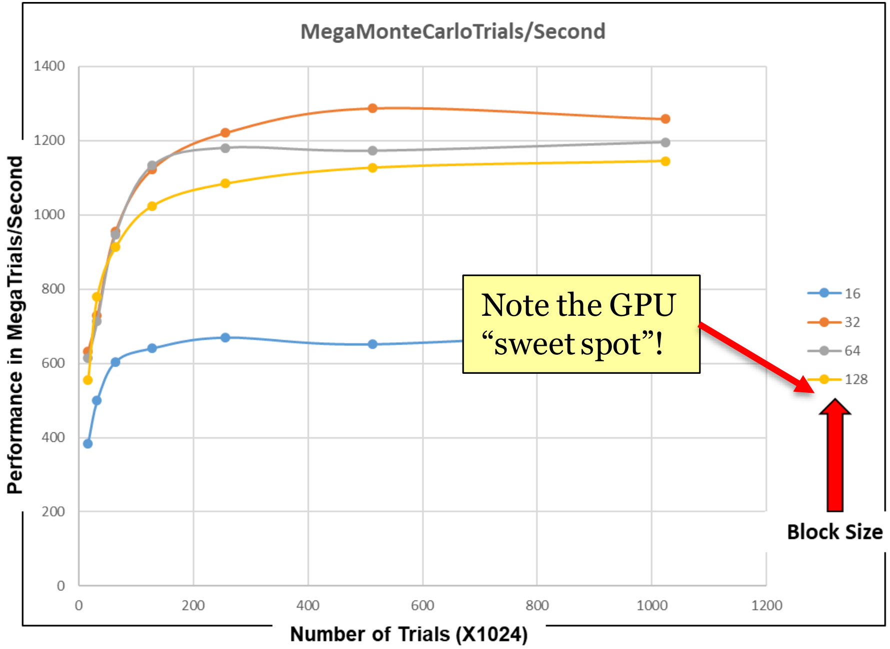
Parallel Programming: OpenCL and CUDA

(300 students in Spring Quarter 2019)

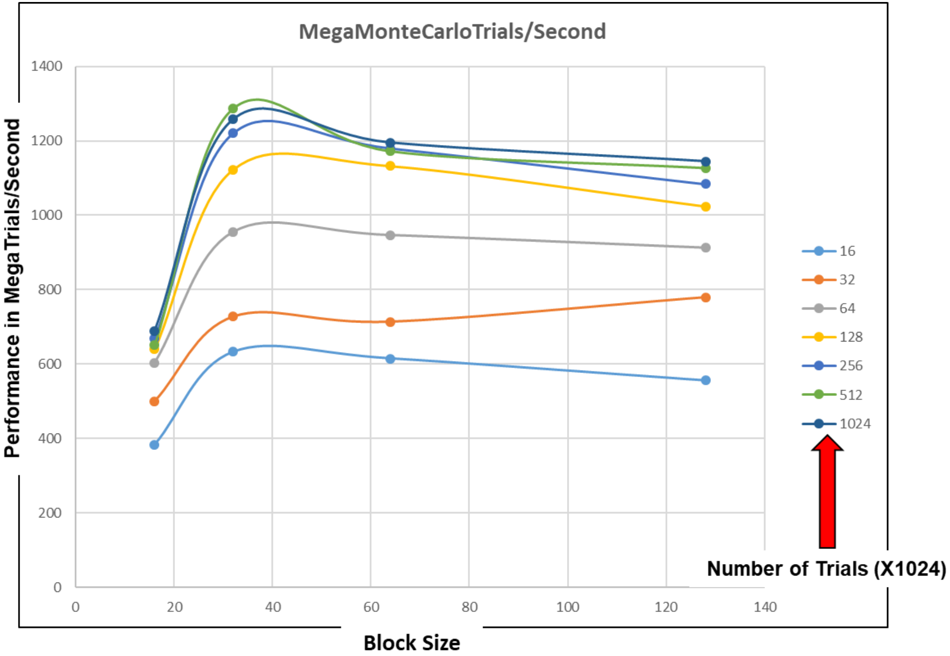
http://cs.oregonstate.edu/~mjb/cs575

Characterizing Parallel Performance

"Doing Parallel Programming *at all* isn't difficult – the trick is doing it *well*!"



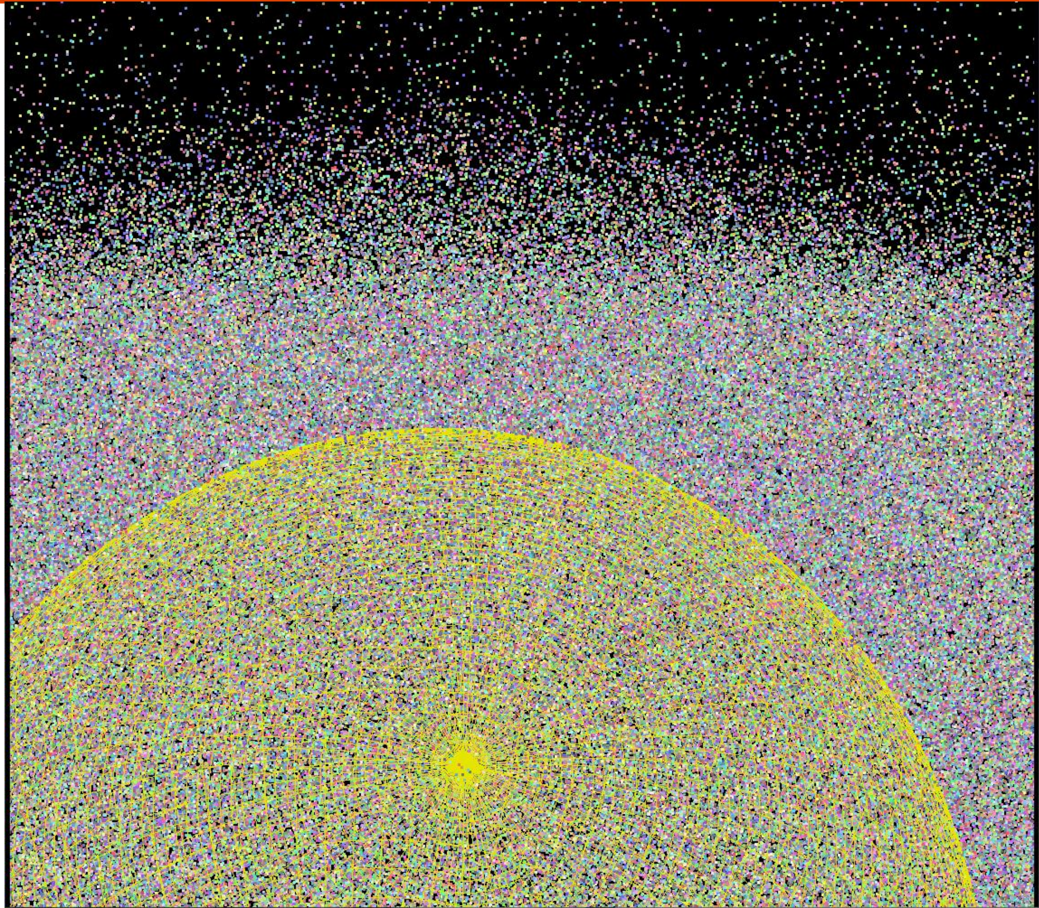
Note the GPU "sweet spot"!



Interoperability between GPU Computing and GPU Rendering

GPU particle system:

Total of 1M particles
Computed and rendered at a rate of
3 GigaParticles/second



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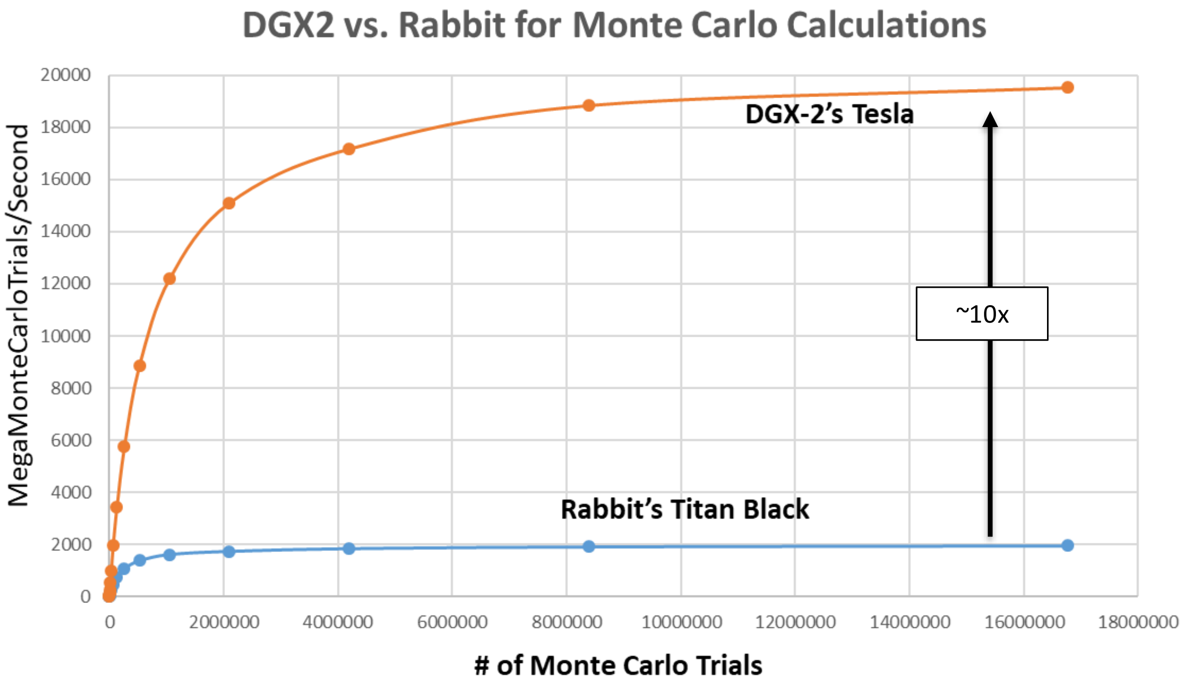
College of Engineering

Enhancing research and teaching

Six NVIDIA DGX-2 systems, each with 16 Tesla V100 GPUs

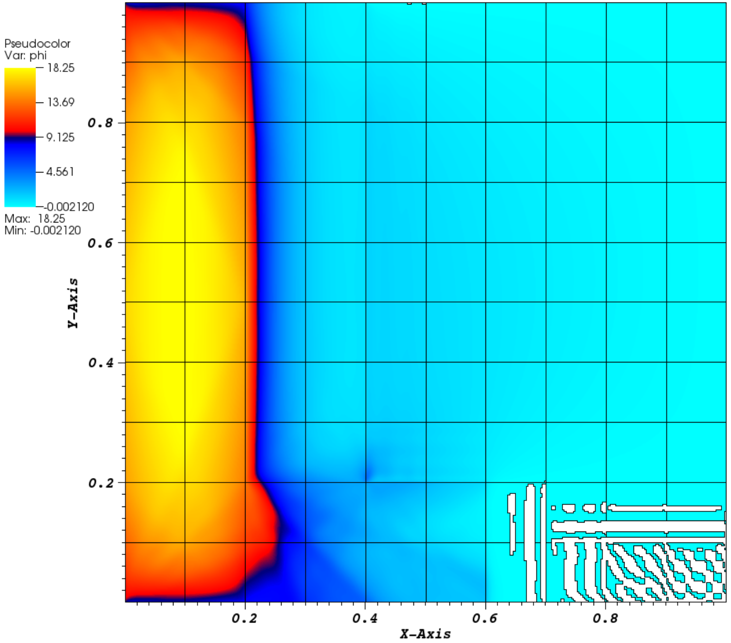
- 5,120 CUDA cores
- 640 Tensor cores

Tesla GPU vs. Titan Black



GPUs in Research

Mike Bailey
mjb@cs.oregonstate.edu

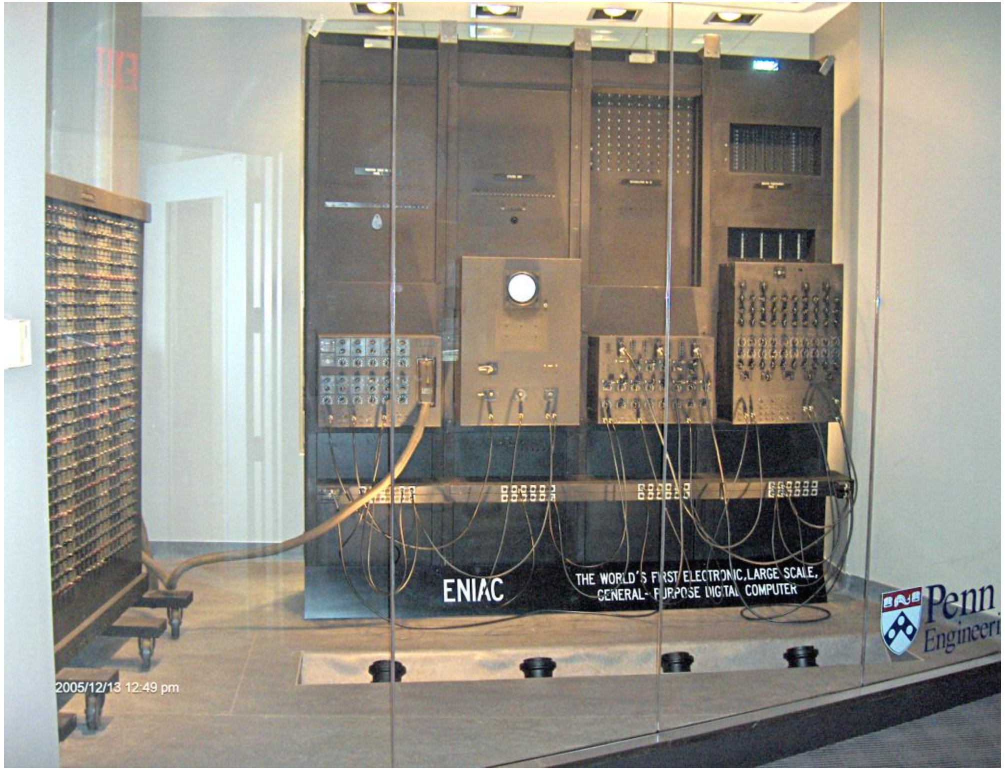


Todd Palmer, Professor of Nuclear Engineering

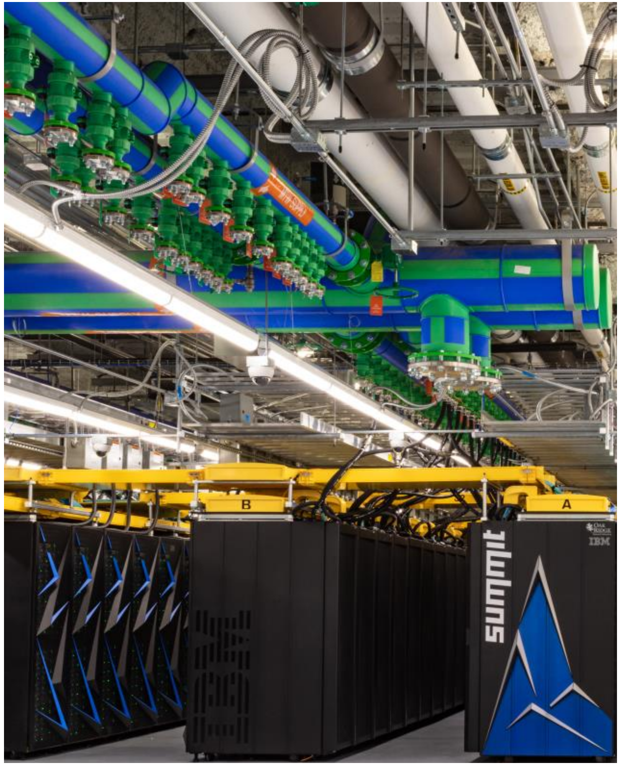
- 27 years of computational nuclear science in academia, U.S. national labs

Oregon State University
College of Engineering

Advanced computing goes hand-in-hand with nuclear science


ENIAC
THE WORLD'S FIRST ELECTRONIC, LARGE SCALE, GENERAL-PURPOSE DIGITAL COMPUTER
Penn Engineeri
2005/12/13 12:49 pm

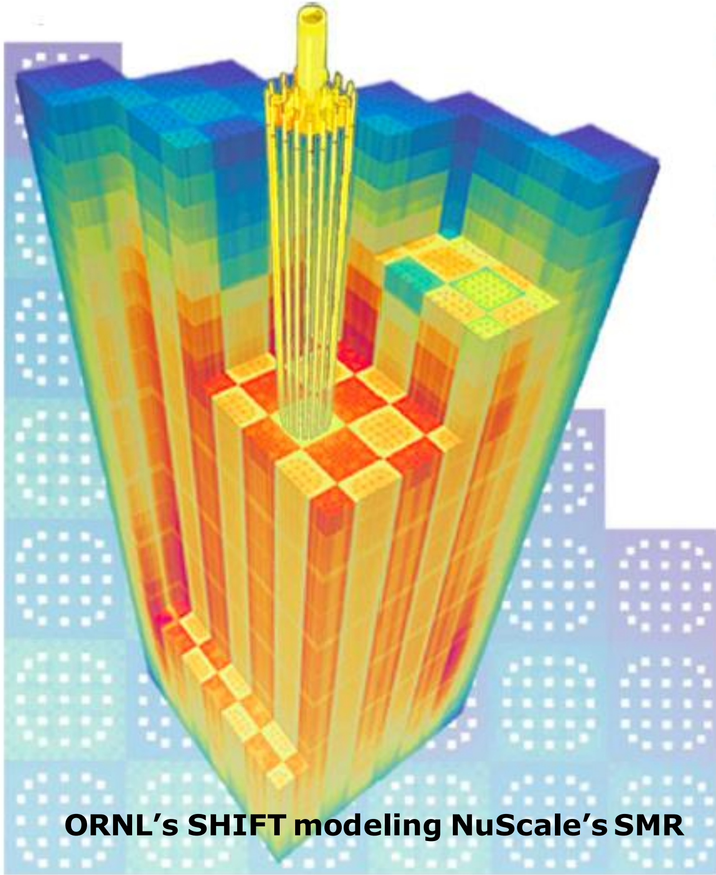
Los Alamos Scientific Laboratory, 1945



Oak Ridge National Laboratory, 2018

Exascale computing research in nuclear

- Reduce margins in the design of advanced nuclear reactors
- Drive development of nuclear fusion
- Predictive science for national security
- Materials under extreme conditions
- Radiation in medicine



ORNL’s SHIFT modeling NuScale’s SMR

Immediate research impact: CeMeNT

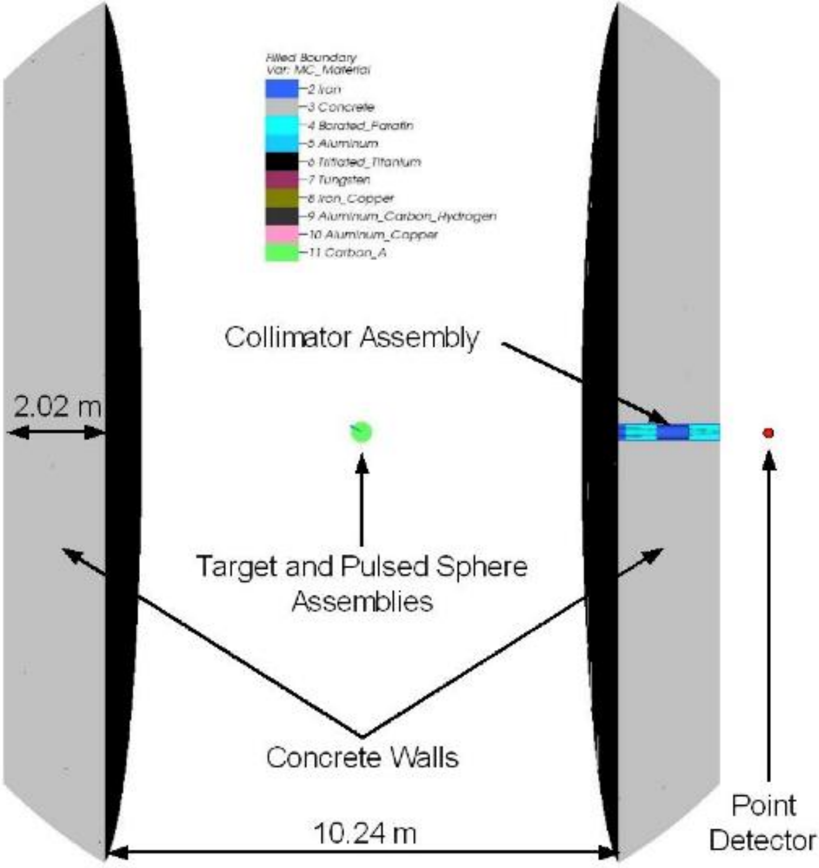
- PSAAP III FIC ($1M/yr, 5 years)
- Dynamic Monte Carlo neutron transport

National Nuclear Security Administration

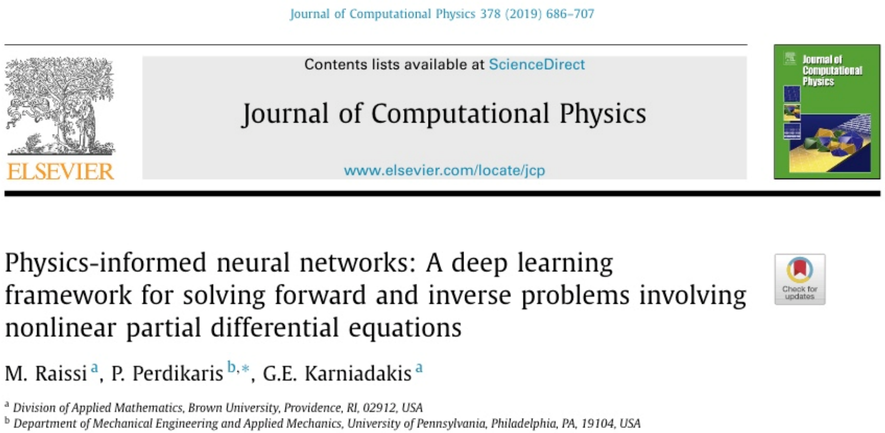
Oregon State University
NSE, ME, EE, CS

University of Notre Dame
AeroE

NC State University
NE, App. Math.



Deep learning: Solving partial differential equations



Journal of Computational Physics 378 (2019) 686–707

Contents lists available at ScienceDirect

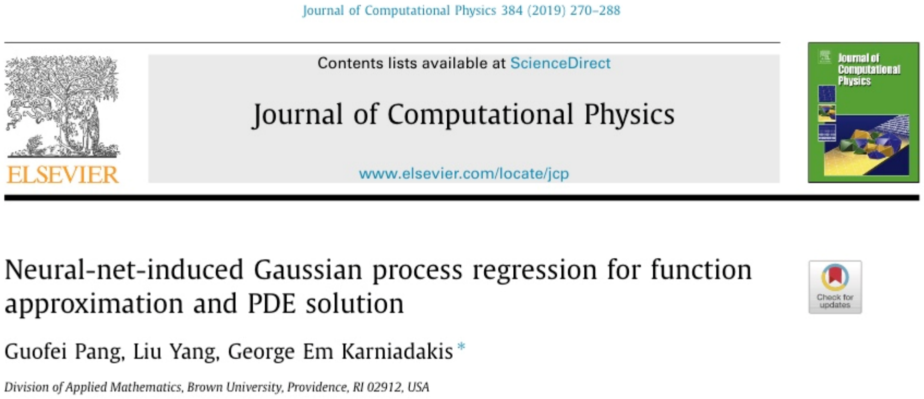
Journal of Computational Physics

www.elsevier.com/locate/jcp

Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations

M. Raissi [a], P. Perdikaris [b,*], G.E. Karniadakis [a]

[a] Division of Applied Mathematics, Brown University, Providence, RI, 02912, USA
[b] Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia, PA, 19104, USA



Journal of Computational Physics 384 (2019) 270–288

Contents lists available at ScienceDirect

Journal of Computational Physics

www.elsevier.com/locate/jcp

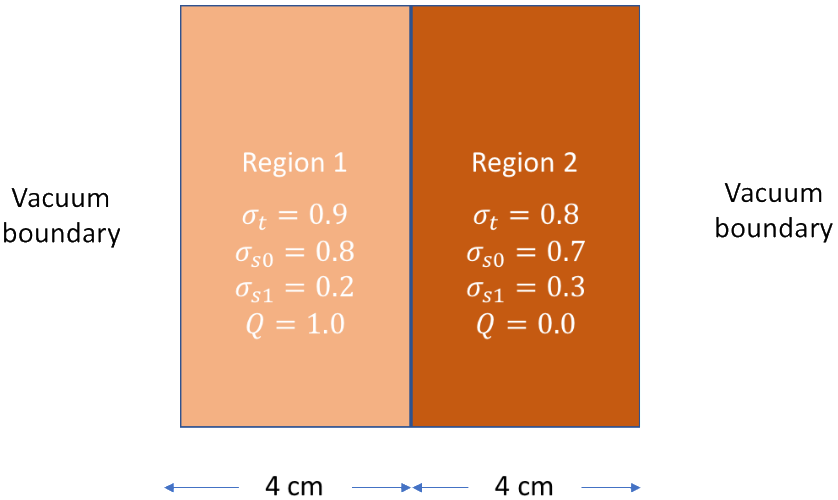
Neural-net-induced Gaussian process regression for function approximation and PDE solution

Guofei Pang, Liu Yang, George Em Karniadakis *

Division of Applied Mathematics, Brown University, Providence, RI 02912, USA

Lawrence Livermore National Laboratory

Artificial neural networks for radiation transport on GPUs



Vacuum boundary

Region 1

$\sigma_t = 0.9$
$\sigma_{s0} = 0.8$
$\sigma_{s1} = 0.2$
$Q = 1.0$

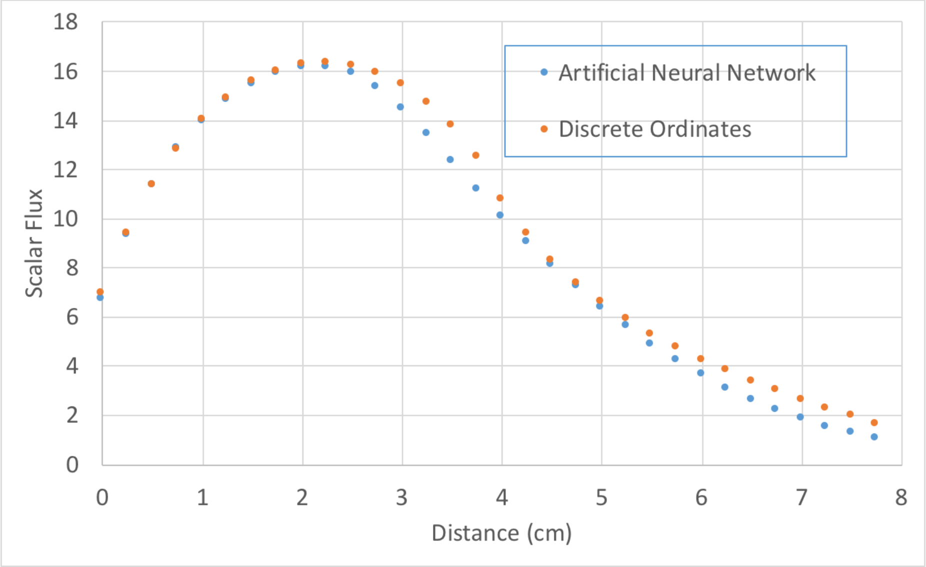
Region 2

$\sigma_t = 0.8$
$\sigma_{s0} = 0.7$
$\sigma_{s1} = 0.3$
$Q = 0.0$

Vacuum boundary

4 cm

4 cm



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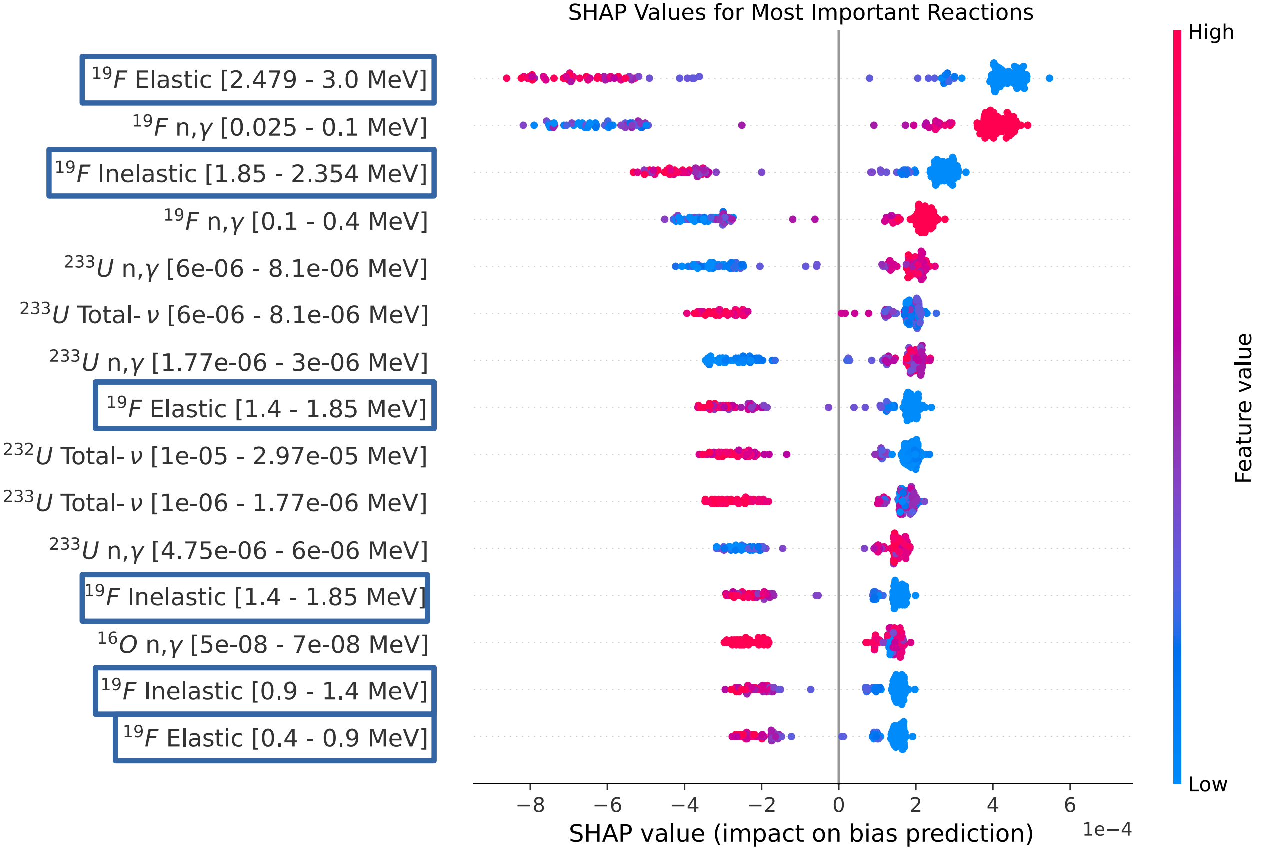
College of Engineering

Reliable, Reproducible Nuclear Criticality Safety Analyses

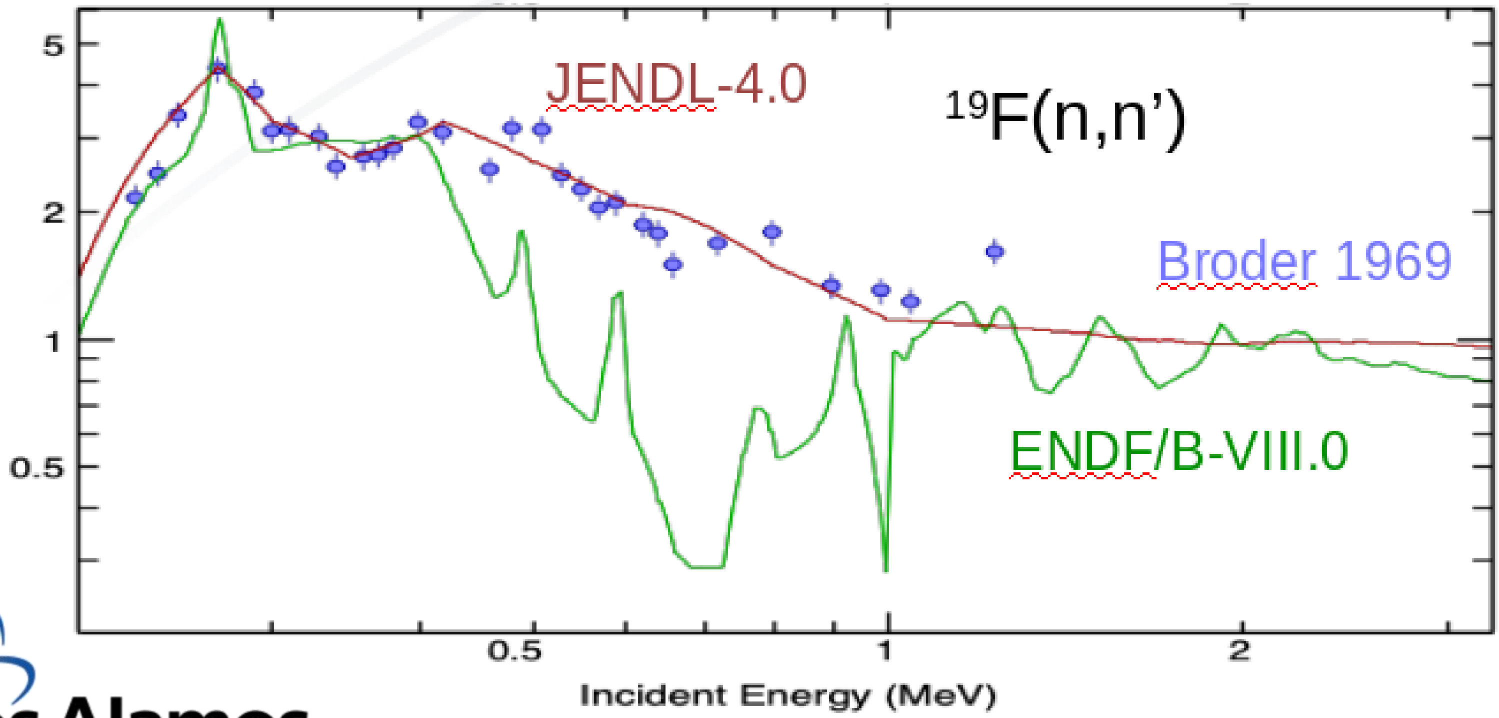
Oregon State University
College of Engineering

Machine Learning explains impact of nuclear data on criticality 'bias'



SHAP Values for Most Important Reactions

Nuclear data anomaly confirmed by expert analysis



Todd Palmer
todd.palmer@oregonstate.edu

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College of Engineering

AI and Robotics Research

Alan Fern, Professor of Computer Science

25 human years of AI research ≈ 222 in AI years

Field moving faster than ever!

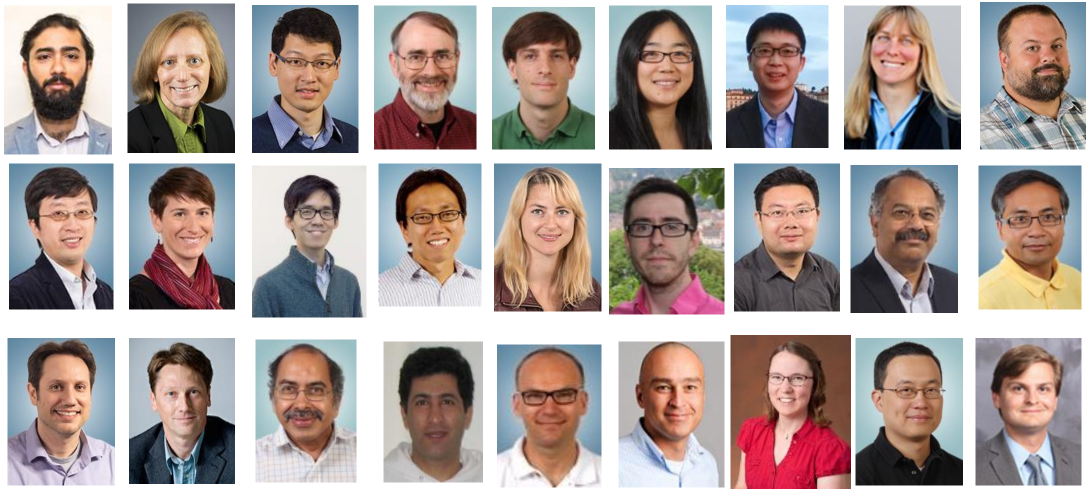
XAI
EXPLAINABLE ARTIFICIAL INTELLIGENCE

DARPA

Machine Common Sense

Oregon State University
College of Engineering

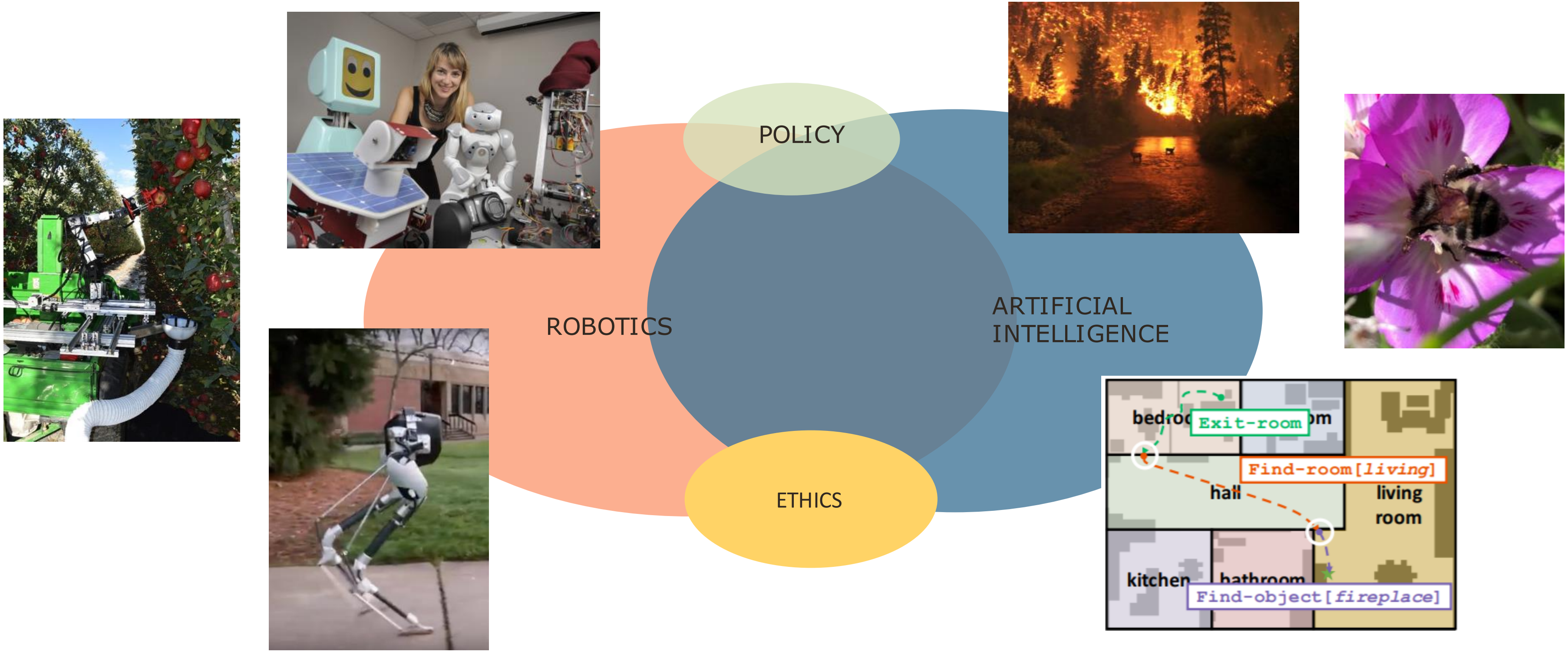
Collaborative Robotics and Intelligent Systems (CoRIS) Institute


28+ Core Faculty (AI, Robotics, Security, Sensors)
60+ Affiliated Faculty across OSU

Robotics Facility

Oregon State University
College of Engineering

Collaborative Robotics and Intelligent Systems (CoRIS) Institute



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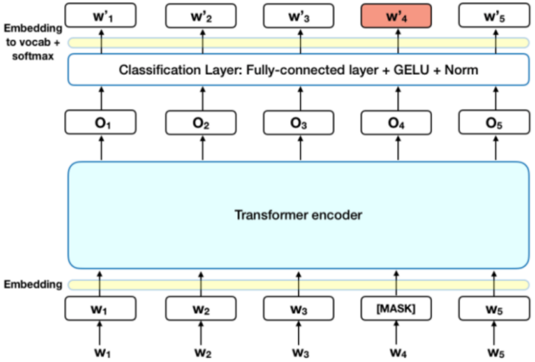
Academic Research in Deep Learning Era

ImageNet Classification

Natural Language Processing



AI Beats World Go Champion

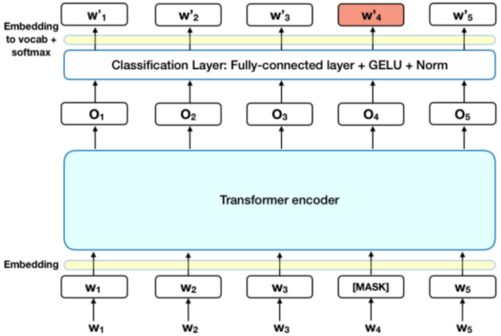
State-of-the-art on established problems primarily from industrial labs!

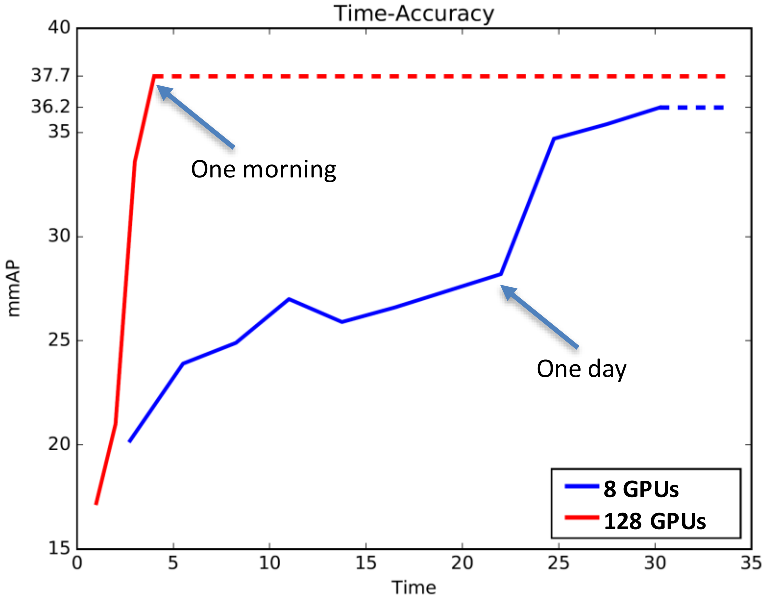
- Leverage huge data sets
- Leverage large numbers of GPUs

Academic Research in Deep Learning Era

ImageNet Classification

Natural Language Processing


w'₁
w'₂
w'₃
w'₄
w'₅
Embedding to vocab + softmax
Classification Layer: Fully-connected layer + GELU + Norm
O₁
O₂
O₃
O₄
O₅
Transformer encoder
Embedding
w₁
w₂
w₃
[MASK]
w₅
w₁
w₂
w₃
w₄
w₅



cf. Peng et al. MegDet: A Large Mini-Batch Object Detector. CVPR 2018

Academic Research in Deep Learning Era

AI Beats World Go Champion

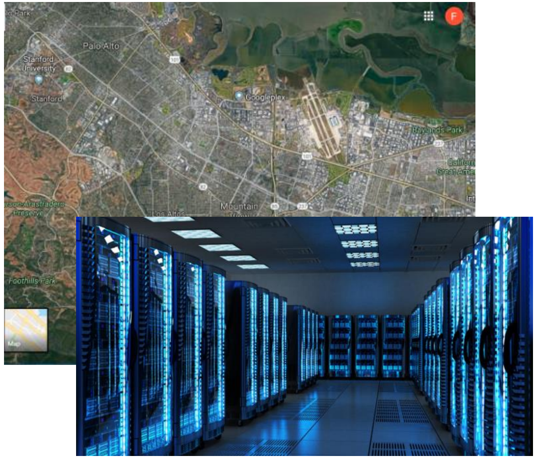
AlphaGo Zero by Google DeepMind learns by playing millions of games against itself.

Cost of Computation ≈ $2.9M

At standard hourly rate.

Academic Research in Deep Learning Era

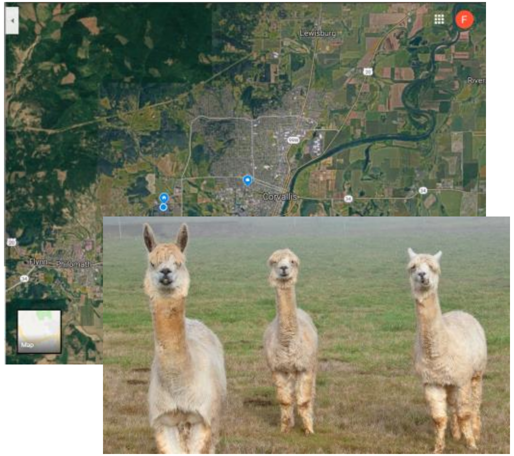
Silicon Valley



100,000s GPUs

~0 Llamas

Corvallis, Oregon



100s GPUs

100+ Llamas

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College of Engineering

What is the role of academic AI research?

Industry Labs

Raw performance on established problems

VS

Academia

New Understanding

New Paradigms

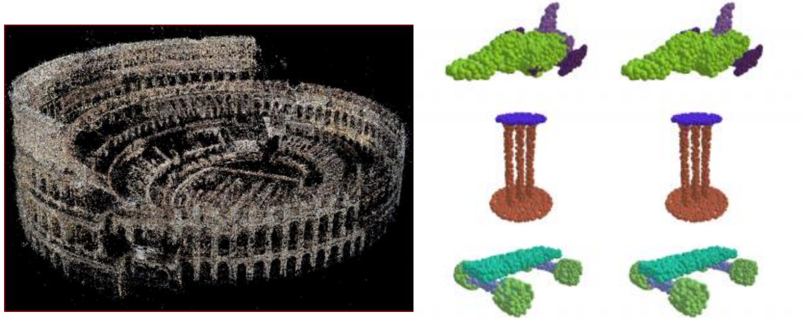
New Problems

Deep Learning on Point Cloud Data

Image Data

- Regular N x M Grid Structure
- Deep Networks exploit regularity!

Point Cloud Data



- Irregular Structure
- New challenges for deep learning

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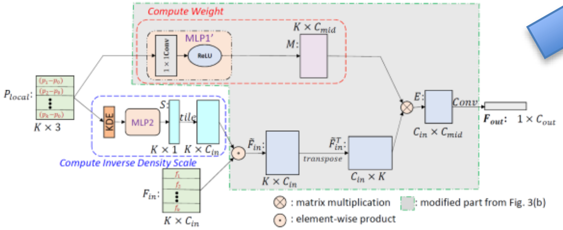
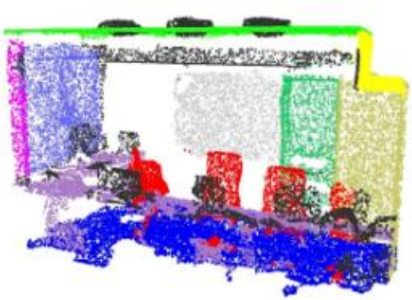
Deep Learning on Point Cloud Data

PointConv Deep Network



Semantic Segmentation



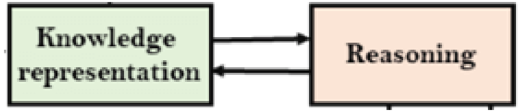
Method	mIoU(%)
ScanNet [5]	30.6
PointNet++ [26]	33.9
SPLAT Net [33]	39.3
Tangent Convolutions [35]	43.8
PointConv	**55.6**

With new DGX-2 GPUs **66.6%** !
(scaled to larger networks)

Professor Fuxin Li – Computer Vision

Synergy of New and Old

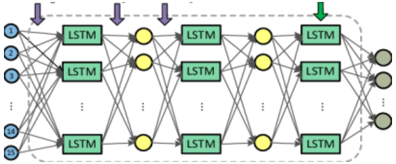
Good Old-Fashion AI



Symbolic Representations/Reasoning

VS

Deep Learning

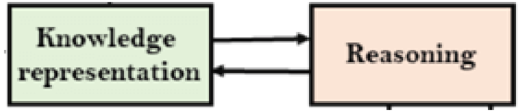


Continuous Distributed Representations

Oregon State University
College of Engineering

Synergy of New and Old

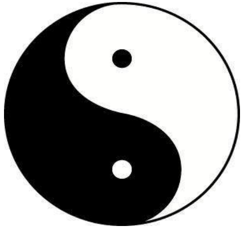
Good Old-Fashion AI



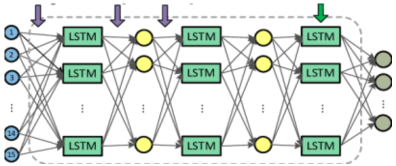
Knowledge representation

Reasoning

Symbolic Representations/Reasoning



Deep Learning



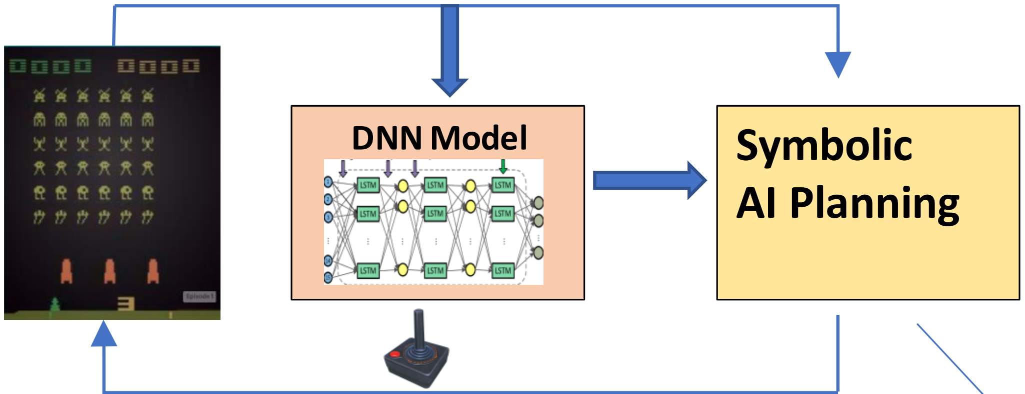
Continuous Distributed Representations

How can we synergistically combine the strengths of both?

How can be exploit GPUs on both sides?

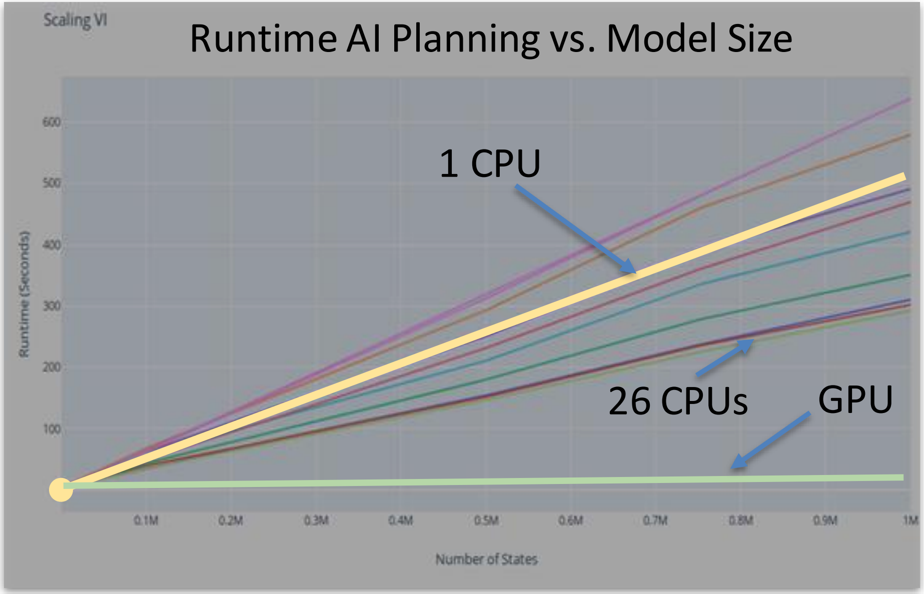
Deep Learning + "Old AI" for Reinforcement Learning

Deep Model-Based RL w/ Symbolic Planning



Scaling to enormous deep network models is a challenge

Deep Learning + “Old AI” for Reinforcement Learning


Runtime AI Planning vs. Model Size

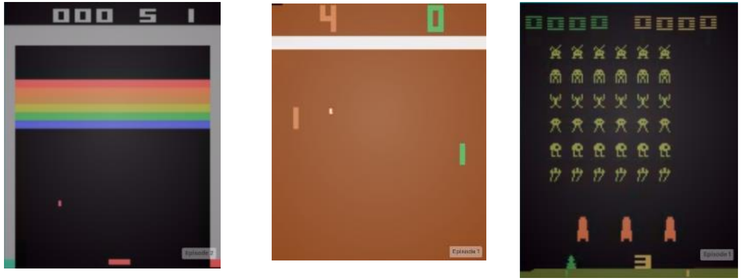
1 CPU

26 CPUs

GPU

Model Size	0.1 M	0.5M	1M	16M
GPU Time	2 s	3.5 s	5 s	30 s
CPU Time	5 s	250 s	520 s	-------

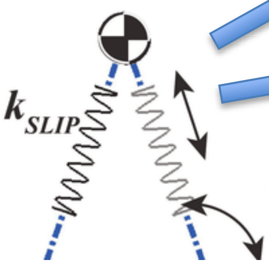
Enables Learning to Solve Atari Games from Raw Pixel Input



Learning to Walk

CASSIE Biped – Agility Robotics

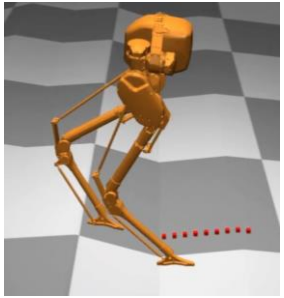
≈



animal-like agility, robustness, energy efficiency — in theory

but ….. traditional control techniques fail

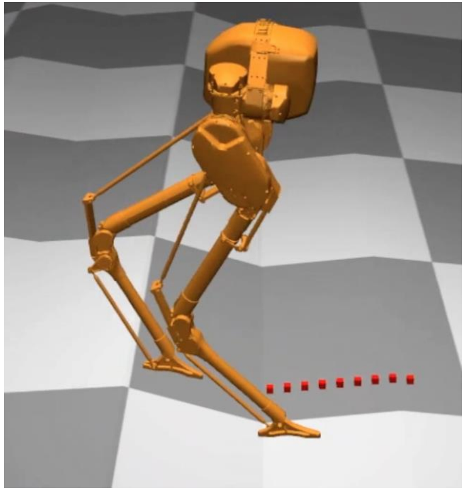
Train deep network controller in simulation (need GPUs!)



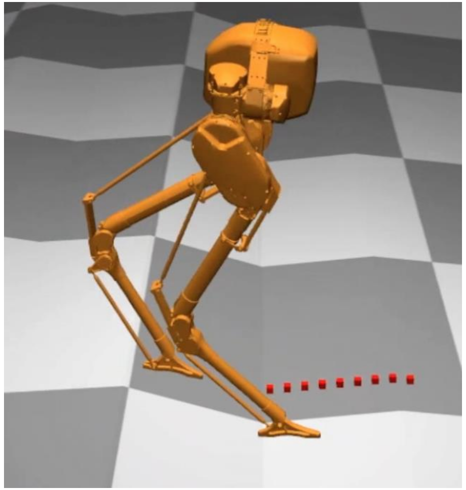
Transfer to real world

Collaboration w/ Professor Jonathan Hurst

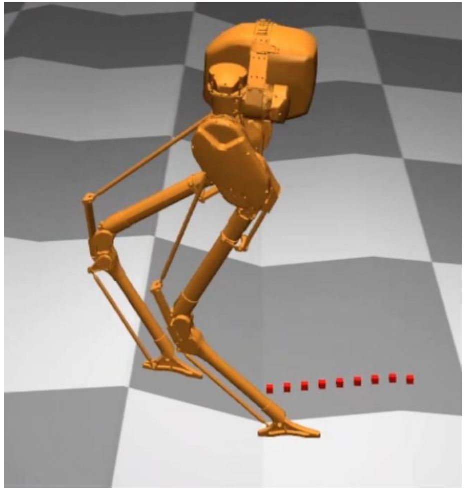
CASSIE very early in training



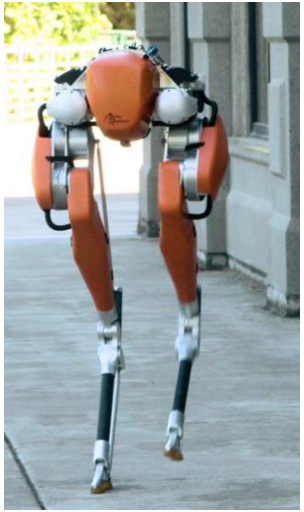
CASSIE after significant training



CASSIE at end of training



CASSIE on treadmill with learned controller



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What is the role of academic AI research?

Industry Labs

Raw performance on established problems

Academia

New Understanding

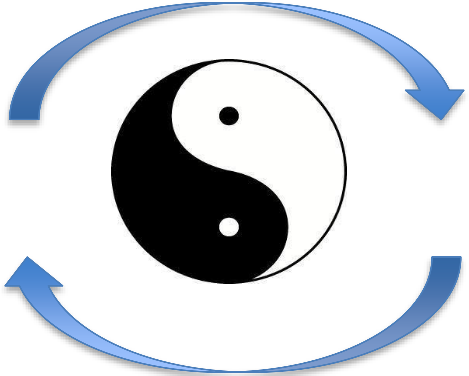
New Paradigms

New Problems

What is the role of academic AI research?

Industry Labs

Raw Performance on Established Problems



Academia

New Understanding

New Paradigms

New Problems

GPUs in Research

Alan Fern
alan.fern@oregonstate.edu

TESLA
NVIDIA
NVIDIA CORPORATION
Santa Clara, California, USA

THANK YOU!